



DEPARTMENT OF THE NAVY
HEADQUARTERS UNITED STATES MARINE CORPS
3000 MARINE CORPS PENTAGON
WASHINGTON, DC 20350-3000

IN REPLY REFER TO:
5090
LF

Dear Sir or Madam:

Thank you for registering with the Camp Lejeune Historic Drinking Water Notification Database. As you may be aware, the purpose of the Notification Database is to notify individuals who may have lived or worked aboard Marine Corps Base Camp Lejeune, North Carolina in 1987, or prior, of potential exposure to contaminated drinking water. We want to ensure that those who may have been exposed are provided with the most up to date information regarding the past water quality aboard the base.

The Department of the Navy continues to fund health activities in an effort to determine when the drinking water may have first been impacted (modeling provides a best estimate of 1953), who may have been exposed, and whether or not there may be any association between exposure to the water and certain health conditions. Fact sheets on health activities are enclosed.

The Department of Veterans Affairs is providing health and disability benefits for certain conditions associated with exposure to contaminants that were found in the drinking water supply at Camp Lejeune in the past. Information regarding qualifying conditions, eligibility requirements, and how to apply are also enclosed.

Please visit our website www.marines.mil/clwater for complete details regarding the Notification Database, on-going studies, and other information. You may also call our toll-free information line, (877) 261-9782, to speak to a representative who can assist you with questions and concerns or contact us by e-mail at clwater@usmc.mil.

We want to ensure the widest dissemination of information to our Marine Corps family. If you know any former residents or employees based at Camp Lejeune in 1987 or prior, please encourage them to register.

Semper Fidelis,

V. A. COGLIANESE
Major General, USMC
Assistant Deputy Commandant
Installations and Logistics (Facilities)

CAMP LEJEUNE

Veteran and family health & disability benefits

In the 1980s, contaminants were found in several wells that provided drinking water at Camp Lejeune, N.C. The contaminants included the volatile organic compounds trichloroethylene (TCE), perchloroethylene (PCE), vinyl chloride, benzene, and other compounds. The primary sources of this contamination were on-base leaking storage tanks and industrial activities, and an off-base dry cleaner. It is estimated that the contaminants were in the water supply from the mid-1950s until February 1985, when the wells were shut down.

Benefits for Camp Lejeune Veterans and family members include health care for 15 conditions listed in the Honoring America's Veterans and Caring for Camp Lejeune Families Act of 2012. In addition, Veterans can receive disability and health care benefits for eight presumptive disease conditions associated with contaminants in the water at Camp Lejeune.

Eligibility timeframe

Veterans, National Guard and reserve members, and family members who lived on the base for at least 30 days (cumulative), between August 1, 1953 and December 31, 1987 are eligible.

What areas are included?

The benefit area includes all areas within the Camp Lejeune and Marine Corps Air Station (MCAS) New River boundaries, as shown on the map on page 4.



Health care for Veterans and family members

The Camp Lejeune Act of 2012 provides health care and health care funding assistance to Veterans and family members who lived on Camp Lejeune, meet the time-on-station and service date requirements, and have one of the covered conditions.

Qualifying health conditions:

- Bladder cancer
- Breast cancer
- Esophageal cancer
- Female infertility
- Hepatic steatosis
- Kidney cancer
- Leukemia
- Lung cancer
- Miscarriage
- Multiple myeloma
- Myelodysplastic syndromes
- Neurobehavioral effects
- Non-Hodgkin's lymphoma
- Renal toxicity
- Scleroderma

Veterans eligible for health care under the *Camp Lejeune Act of 2012* may enroll in VA health care and receive medical services for any of the 15 covered health conditions, and eight disability conditions at no cost.

To enroll in VA health care, [apply](https://www.va.gov/healthbenefits/apply/) at www.va.gov/healthbenefits/apply/ or call 1-877-222-8387 for help. Inform VA staff that you served on active duty at Camp Lejeune for at least 30 days during the covered time period.

Family member health care reimbursement

Dependent family members of Veterans who also resided at Camp Lejeune during the qualifying period are eligible for reimbursement of out-of-pocket medical expenses related to any of the 15 covered health conditions. Reimbursement for medical claims can be paid for care up to two years prior to the date of application for benefits. VA can only pay for treatment costs that remain after payment from your other health plans.

Apply online for reimbursement at www.clfamilymembers.fsc.va.gov/ or call 1-866-372-1144 for help.

What type of evidence can I submit with my application?

- Documentation showing a legal dependent relationship to a Veteran who served at Camp Lejeune, such as a marriage license or birth certificate.
- Documentation showing you lived on the base for 30 days or more between August 1, 1953 and December 31, 1987, such as copies of orders. VA has the base housing records, but additional evidence is welcome.
- Documentation showing you paid health care expenses for a covered condition or an illness caused by the covered condition.

For information call

VA Health Care 1-877-222-8387

VA Benefits 1-800-827-1000

**CL Family Health Care
1-866-372-1144**

Veterans disability compensation

The Department of Veterans Affairs has established a presumption of service connection for eight conditions associated with exposure to contaminants in the water supply at Camp Lejeune, N.C. These conditions were determined after a review of scientific and medical literature on health effects related to the contaminants of concern at Camp Lejeune.

The presumption applies to active duty, reserve, and National Guard members exposed to contaminants in the water supply at Camp Lejeune for at least 30 days between August 1, 1953 and December 31, 1987, and who later developed one or more of the following eight conditions:

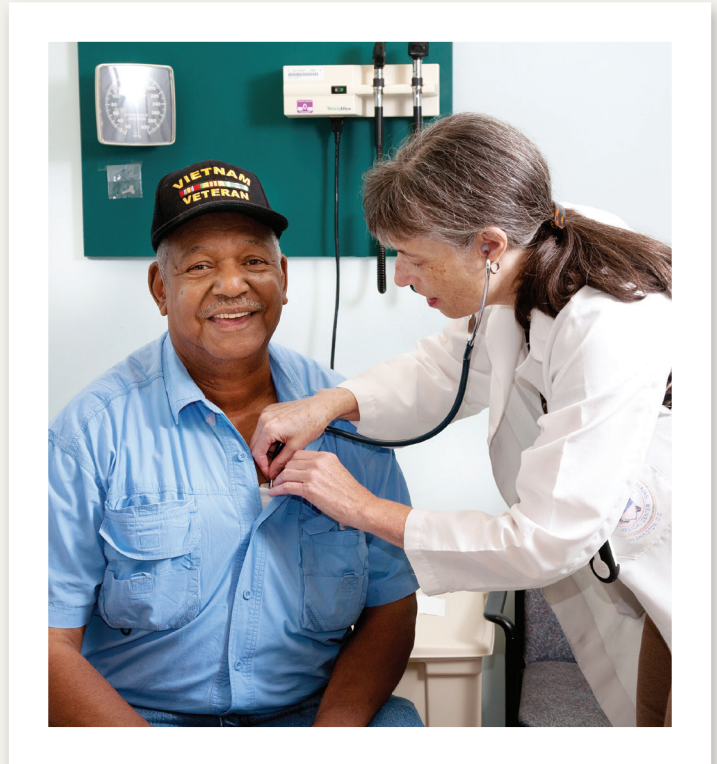
- Adult leukemia
- Aplastic anemia and other myelodysplastic syndromes
- Bladder cancer
- Kidney cancer
- Liver cancer
- Multiple myeloma
- Non-Hodgkin's lymphoma
- Parkinson's disease

Presently, these are the conditions for which VA has determined there is sufficient scientific and medical evidence to support presumptive service connection; however, VA will continue to review relevant information on other conditions as it becomes available.

If a Veteran is diagnosed with one of these conditions, VA presumes that his/her Camp Lejeune service caused the condition, and disability compensation can be awarded.

Evidence requirements

Veterans must submit records that show you served at Camp Lejeune or MCAS New River for at least 30 days (cumulative), between August 1, 1953 and December 31, 1987, in an active duty, reserve, or National Guard capacity.



The medical evidence must show you have a current disease on the list of presumptive conditions related to Camp Lejeune.

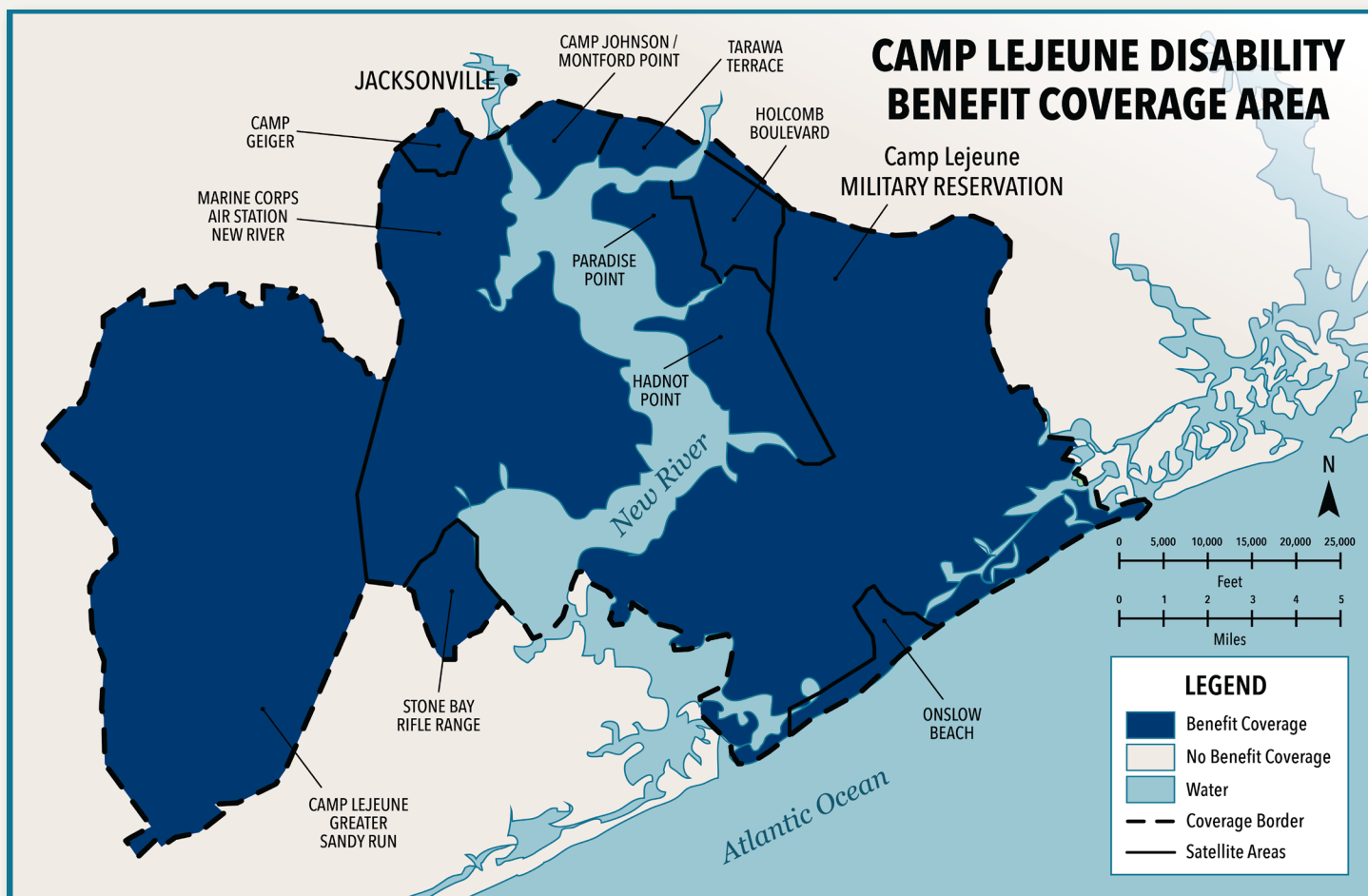
How to apply for disability benefits

Apply online using eBenefits. State on your application that you are filing for one of the presumed Camp Lejeune illnesses.

- Include evidence of service at Camp Lejeune during the required timeframe.
- Provide medical evidence showing your diagnosis.

For additional assistance you can work with an accredited representative or agent or, go to a VA regional office and talk to a VA employee. You can find your nearest regional office on our Facility Locator page at <http://benefits.va.gov/benefits/offices.asp>.

For more information on how to apply and for tips on making sure your claim is ready to be processed by VA, visit our [How to Apply](https://explore.va.gov/disability-compensation) page at <https://explore.va.gov/disability-compensation>.



Camp Lejeune Historic Drinking Water Database

The Marine Corps maintains an information database for those who may have been exposed to contaminants in the drinking water at Camp Lejeune between August 1, 1953 and December 31, 1987.

To be added to the Camp Lejeune Historic Drinking Water Notification Database, or for more information, please visit: <http://www.marines.mil/clwater/>. You can also contact the Camp Lejeune Historic Drinking Water Call Center at (877) 261-9782 or e-mail clwater@usmc.mil.

The Marine Corps continues to work diligently to both identify and communicate with registrants by sending them the latest information via mail and email. Please share information about the registry with anyone who may have been at Camp Lejeune between the dates noted above and encourage them to participate.



U.S. Department
of Veterans Affairs

Camp Lejeune – Chapter A Report



Summary and Findings: Analyses and Historical Reconstruction of Drinking Water in the Hadnot Point and Holcomb Boulevard Water Treatment Plants Service Areas

Background

U.S. Marine Corps Base Camp Lejeune, North Carolina was established in 1942. In 1982, the Marine Corps discovered specific volatile organic compounds (VOCs) in the drinking water provided by two of the eight water distribution systems on base. The Agency for Toxic Substances and Disease Registry has several projects underway to help Marines, civilians, health officials, and other interested parties understand more about the drinking water contamination and whether it affected the health of persons living or working on the base during the period 1968-1985.

Using Research to Understand Health Effects

ATSDR is determining associations between human health effects and exposures to VOCs in drinking (finished) water at Camp Lejeune. To accomplish this, ATSDR used water modeling to determine which areas at Marine Corps Base Camp Lejeune received VOC-contaminated drinking water in the past. Water modeling is a method of analysis that enabled ATSDR to estimate drinking water concentrations for the period 1942-2008. This work will help ATSDR epidemiologists determine what populations were exposed to contaminants and at what levels they were exposed.

Chapter A: Summary and Findings presents summaries of analyses and results of reconstructed VOC-contaminant concentrations in water supply wells and drinking water within the Hadnot Point and Holcomb Boulevard water treatment plant service areas. This report summarizes previous analyses and investigations—Chapters B, C, and D—and results of water modeling investigations. Completing Chapter A and the eight supplements required discovery, extraction, and analyses of data and information from tens of thousands of federal and state government documents.

This report is a companion to previously published reports on geohydrologic data (Chapter B), selected groundwater contaminants at Installation Restoration Program sites (Chapter C), and occurrence of selected groundwater contaminants at above- and underground storage tank sites (Chapter D).

Chapter A Supplements

1. Water supply well operations
2. Reconstruction of historical water supply well operations
3. Water level data and groundwater flow
4. Simulation of 3-dimensional groundwater flow
5. Reconstruction of contaminant concentrations using linear control model methodology
6. Reconstruction of VOC concentrations in groundwater
7. Simulation of LNAPL migration and concentrations in groundwater
8. Intermittent transfers of drinking water between the Hadnot Point and Holcomb Boulevard water distribution systems



Information in Chapter A

ATSDR's water-modeling techniques and historical reconstruction process were used to estimate monthly contaminant levels in drinking water within the Hadnot Point and Holcomb Boulevard water treatment plant service areas.

ATSDR estimates that drinking water from the Hadnot Point water treatment plant exceeded the current maximum contaminant levels (MCL) for one or more VOCs from August 1953 through January 1985. The specific VOCs that ATSDR examined are:

- trichloroethylene (TCE),
- tetrachloroethylene (PCE),
- *trans* 1,2-dichloroethylene, (1,2-tDCE)
- vinyl chloride, and
- benzene.

With the exception of *trans* 1,2-dichloroethylene, these chemicals have been classified as causing or probably causing cancer (carcinogenic). Non-cancer diseases associated with the chemicals are aplastic anemia, infertility, kidney diseases, liver disease, lupus, miscarriage, Parkinson's disease, scleroderma, and skin disorders.

What is a maximum contaminant level?

The maximum contaminant level (MCL) is the highest level of a contaminant that is allowed in drinking water. Drinking water, including bottled water, reasonably may be expected to contain at least small amounts of some contaminants. The presence of contaminants does not necessarily indicate that water poses a health risk. EPA sets standards for approximately 90 contaminants and indicators in drinking water. The MCL is based on a scientific opinion after a careful review of scientific literature for both cancer and non-cancer health effects.



The Hadnot Point Water Treatment Plant opened in 1942 and provided water to both the Hadnot Point and Holcomb Boulevard service areas. The Hadnot Point water system was contaminated with TCE, PCE and refined petroleum products. The Holcomb Boulevard Water Treatment plant came online in 1972. The Holcomb Boulevard system was not contaminated, except for periodic transfers of water from the Hadnot Point Water System.

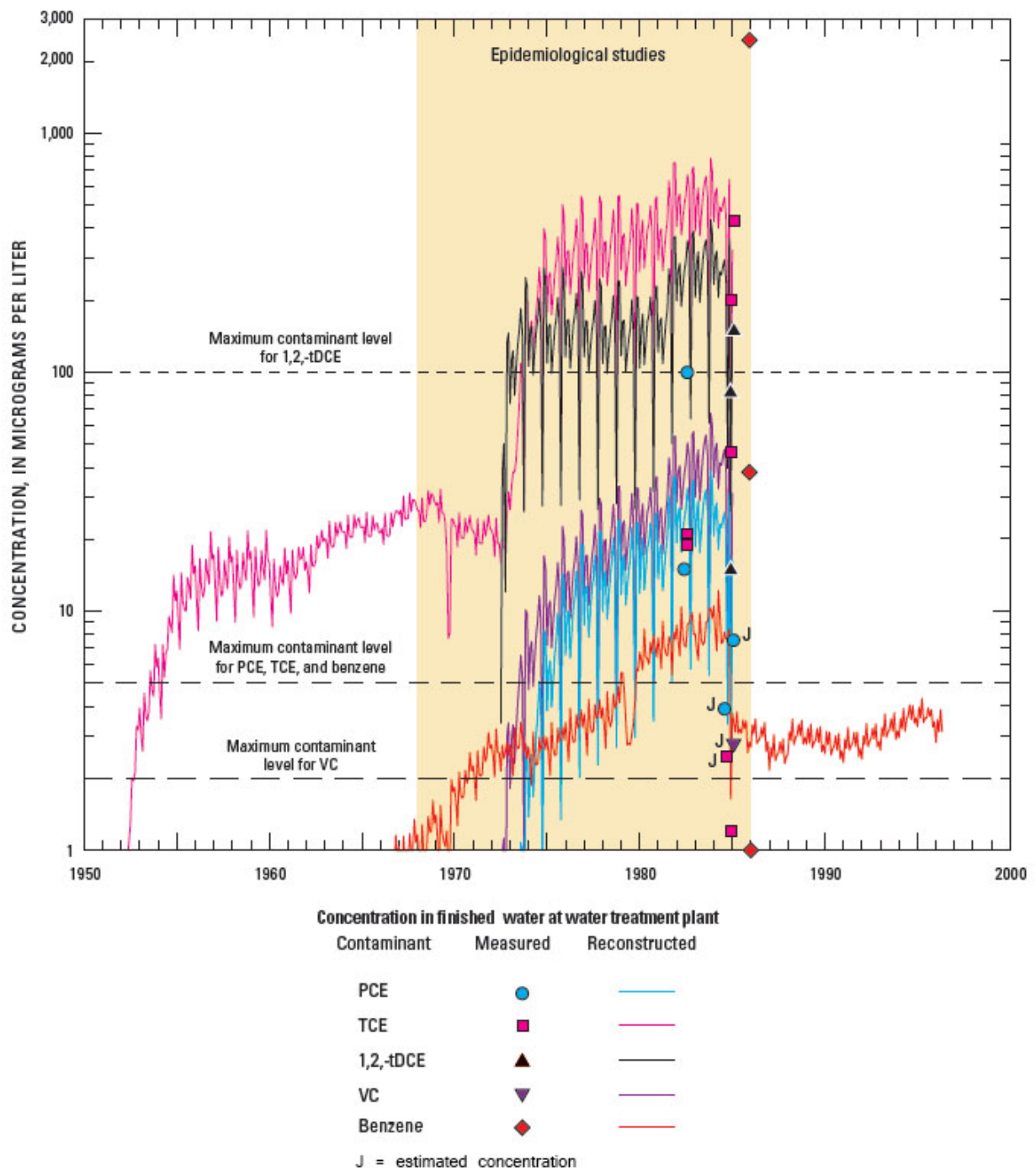
Trichloroethylene

Within the Hadnot Point service area, drinking water concentrations exceeded the maximum contaminant level (MCL) for trichloroethylene (TCE) from August 1953-January 1985. Reconstructed TCE concentrations in Hadnot Point drinking water reached a maximum level of 783 µg/L during November 1983. The maximum TCE level in Holcomb Boulevard was 66 µg/L in February 1985. The MCL for TCE is 5 µg/L. It was set in 1989.

Tetrachloroethylene

Within the Hadnot Point service area, drinking water concentrations exceeded the maximum contaminant level (MCL) for tetrachloroethylene (PCE) from August 1974-January 1985. Reconstructed PCE concentrations in Hadnot Point drinking water reached a maximum level of 39 µg/L in November 1983. The maximum PCE level in Holcomb Boulevard drinking water was 3 µg/L in February 1985. The MCL for PCE is 5 µg/L. It was set in 1992.

Reconstructed drinking water concentrations at the Hadnot Point Water Treatment Plant



***Trans*-1,2-dichloroethylene**

Within the Hadnot Point service area, drinking water concentrations exceeded the maximum contaminant level (MCL) for *trans*-1,2-dichloroethylene (1,2-tDCE) from November 1972-January 1985. Reconstructed 1,2-tDCE concentrations in Hadnot Point drinking water reached a maximum level of 435 µg/L during November 1983. The maximum 1,2-tDCE level in Holcomb Boulevard drinking water was 33 µg/L in February 1985. The MCL for 1,2-tDCE is 100 µg/L. It was set in 1992.

Vinyl chloride

Within the Hadnot Point service area, drinking water concentrations exceeded the maximum contaminant level (MCL) for vinyl chloride from November 1972-January 1985. Reconstructed vinyl chloride concentrations in Hadnot Point drinking water reached a maximum level of 67 µg/L during November 1983. The maximum vinyl chloride level in Holcomb Boulevard drinking water was 6 µg/L during February 1985. The MCL for vinyl chloride is 2 µg/L. It was set in 1989.

Benzene

Within the Hadnot Point service area, drinking water concentrations exceeded the maximum contaminant level (MCL) for benzene from January 1979-January 1985. Reconstructed benzene concentrations in Hadnot Point drinking water reached a maximum level of 12 µg/L during April 1984. The maximum benzene level in Holcomb Boulevard drinking water was 3 µg/L during several months in 1972. The MCL for benzene is 5 µg/L. It became effective in 1989.

Next Steps

The estimated monthly concentrations of selected VOCs in drinking water provided in this report gives epidemiologists information they need to estimate exposure for human health studies. ATSDR is working on four health studies that are expected to be released in 2013 and 2014.

ATSDR Health Studies for Camp Lejeune

Birth Defects and Childhood Cancer Study—Looks at whether children born from 1968-1985 to mothers who were exposed to contaminated drinking water at Camp Lejeune have increased risk for specific birth defects and childhood cancers

Health Survey of Marine Corps Personnel and Civilians—Will help determine whether contaminated water may have affected people's health and provide more information about how environmental and chemical exposures affect human health

Male Breast Cancer Study—Will look at cases of male breast cancer among Marines to determine whether a link exists between cases and exposure to contaminated drinking water at Camp Lejeune

Mortality Study—Looks at all causes of death to determine if there is a link between specific causes of death and exposure to contaminated drinking water at Camp Lejeune

Camp Lejeune Health Studies

Adverse Birth Outcomes

Study Results

Evaluation of contaminated drinking water and preterm birth, small for gestational age, and birth weight at Marine Corps Base Camp Lejeune, North Carolina: A cross-sectional study

Study Purpose

The purpose of this study was to determine if maternal exposures to contaminants in drinking water at Camp Lejeune were associated with preterm birth and fetal growth retardation. This study is a reanalysis of a previous study, which incorrectly categorized as “unexposed” some maternal exposures before June 1972 based on information available at the time.

Besides considering the re-categorized births to exposed women, the Agency for Toxic Substances and Disease Registry (ATSDR) recreated monthly estimates of past levels of drinking water contamination using computer models. These estimates were not available when the first study was conducted.

Drinking water at Camp Lejeune was contaminated with volatile organic compounds (VOCs) including trichloroethylene (TCE), tetrachloroethylene (PCE), benzene, 1,2-dichloroethylene (DCE) and vinyl chloride from the 1950s through 1985.

What Was Studied

The study included live singleton births 28-47 weeks gestation weighing 500 grams or more. The births occurred between 1968 and 1985 to women who resided on base for at least one week before giving birth. These years were chosen because computerized birth certificates in North Carolina became available in 1968 and the contaminated wells on base were shut down in 1985. The authors cross referenced birth certificate data for Onslow County, NC, where Camp Lejeune is located, with Camp Lejeune housing records and identified 11,896 births that met the study criteria.

Outcomes of interest in this study were preterm birth and fetal growth retardation. Fetal growth retardation was measured by reduced mean birth weight (MBW), term low birth weight (TLBW), and small for gestational age (SGA). Information about these outcomes was obtained from birth certificates. Preterm births were defined as births occurring at less than 37 weeks of gestation. Gestational age was calculated using date of mother’s last menstrual period from the birth certificate. TLBW was defined as full-term babies (37 weeks or more gestation) weighing less than 2,500 grams at birth. SGA births were defined as births weighing less than the 10th percentiles using sex- and race-specific weight by gestational week norms. For the MBW analysis, only full-term infants were included.

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Features of this Study

Because of the lack of exposure information, ATSDR used extensive water modeling to reconstruct exposures before 1987. The water modeling allowed the investigators to examine associations between monthly estimates of exposures to VOCs in drinking water at the residences and the risk of adverse birth outcomes.

Conclusion and Key Results

The following effects were seen in births from 1968-1985 to women exposed to contaminated drinking water at Camp Lejeune. These findings also apply to women who gave birth before 1968 if they were exposed to similar levels of VOCs-contaminated drinking water.

- Exposure to PCE in the womb was associated with preterm birth (before 37 weeks of pregnancy).
 - For PCE and preterm birth, the strongest association was seen for exposures during the 2nd trimester (4th to 6th months).
- Exposure to TCE in the womb was associated with SGA, TLBW and reduced MBW.
 - The risk of TLBW increased with increasing levels of exposure to TCE during the 2nd trimester.
 - The finding for SGA is consistent with findings from a previous study conducted in Woburn, MA.
- Exposure to benzene in the womb was associated with TLBW.
 - The risk of TLBW increased with increasing levels of exposure to benzene throughout the pregnancy.

Camp Lejeune Health Studies

Birth Defects and Childhood Cancers Journal Article Study Design and Outcomes

Exposure to Contaminated Drinking Water and Specific Birth Defects and Childhood Cancers at Marine Corps Base Camp Lejeune, North Carolina

Study Purpose

The purpose of this study was to determine if maternal exposures to the drinking water contaminants at Camp Lejeune increased the risk of neural tube defects (NTDs), oral clefts, and childhood hematopoietic cancers. This study also examined whether children exposed to contaminated drinking water during the first year of life had an increased risk of childhood cancers. Drinking water at Camp Lejeune was contaminated with volatile organic compounds (VOCs) including trichloroethylene (TCE), tetrachloroethylene (PCE), benzene, 1,2-dichloroethylene (DCE) and vinyl chloride from the 1950s through 1985.

What Was Studied

The Agency for Toxic Substances and Disease Registry (ATSDR) surveyed the parents of 12,598 children during 1999-2002 to identify potential cases of birth defects and childhood cancers. ATSDR asked parents if their child had a birth defect or developed a childhood cancer. To be eligible for the survey, the mother had to reside on base some time during her pregnancy and children had to be born between 1968-1985.

The survey's participation rate was approximately 76% (ATSDR 2003). Survey participants reported 106 cases: 35 NTDs, 42 oral clefts, and 29 childhood hematopoietic cancers. ATSDR made extensive efforts to obtain medical information from health providers to confirm reported cases. ATSDR was able to confirm 15 NTDs, 24 oral clefts, and 13 cancers. Only confirmed cases from the survey were eligible for the study.

Based on the survey results, the study focused on NTDs (spina bifida and anencephaly), oral clefts (cleft lip and cleft palate), and childhood hematopoietic cancers (leukemia and non-Hodgkin's lymphoma [NHL]) diagnosed before 20 years of age.

Features of this Study

Due to the lack of exposure information, ATSDR used extensive water modeling to reconstruct exposures before 1987. This study is unique because it used this water modeling to thoroughly examine associations between monthly exposures to VOCs in drinking water at the residence and the risk of developing specific birth defects and childhood cancers. Most previous studies that have evaluated these associations have done so at the broad water system level versus drinking water at the residence.

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Conclusion and Key Results

ATSDR's study results suggested associations between TCE and benzene in Camp Lejeune drinking water and NTDs.

- In this study, these effects were seen in children born from 1968-1985 whose mothers were exposed to contaminated drinking water in their residences at Camp Lejeune.
- During the first trimester of pregnancy, the risk of a NTD increased with increasing levels of exposure to TCE.
 - This finding is consistent with a previous study conducted in New Jersey, which found similar risk of NTDs when exposed to TCE during the first trimester.
- Investigators observed an association between NTDs and first trimester exposure to benzene. ATSDR was unable to evaluate whether increasing levels of exposure to benzene were associated with increased risk of NTDs because of small numbers of exposed cases.

ATSDR's study results suggested weaker associations between 1st trimester exposure to PCE, vinyl chloride, and 1,2- DCE and childhood hematopoietic cancers such as leukemia.

- These associations are weaker than those found for NTDs.
- Researchers did not observe an increased risk for these cancers with increasing levels of exposure to the chemicals.

The study found no evidence suggesting any other associations between outcomes and exposures.

- For childhood cancers, ATSDR also looked at exposures during the second and third trimesters, the entire pregnancy as a whole, and exposures in the first year of life. The investigators did not see any associations between these chemicals with these time periods.
- Exposure to contaminants in Camp Lejeune drinking water did not increase the risk of oral clefts.

Camp Lejeune Health Studies

Mortality study of civilian employees exposed to contaminated drinking water at USMC Base Camp Lejeune: A retrospective cohort study

Study Purpose

The purpose of the study was to determine whether potential exposures to the drinking water contaminants at Camp Lejeune are associated with increased risk of death from specific cancers and other chronic diseases among those who were employed at the base. The contaminants included trichloroethylene (TCE), tetrachloroethylene (also known as perchloroethylene or PCE), benzene, and two contaminants that are formed when TCE or PCE degrade in ground water: 1,2-dichloroethylene and vinyl chloride.

What Was Studied

The study evaluated specific causes of death in 4,647 full-time workers who were employed at Camp Lejeune during 1973-1985¹. We also evaluated a comparison group of 4,690 full-time workers who were employed at Camp Pendleton during 1973-1985 but were not employed at Camp Lejeune during this period. The Camp Pendleton workers were not exposed to contaminated drinking water.

Cause of death data from 1979-2008 were used to study the Camp Lejeune and Camp Pendleton cohorts. Information on causes of death was obtained from the National Death Index (NDI) of the National Center for Health Statistics. The study included all underlying causes of death that other studies have shown to be associated with one or more of the chemicals found in the drinking water at Camp Lejeune. Causes of death were selected based on literature reviews conducted by the U.S. Environmental Protection Agency (EPA), the National Toxicology Program (NTP), the International Agency for Research on Cancer (IARC), and Agency for Toxic Substance and Disease Registry (ATSDR).

The causes of death that were studied include:

- Amyotrophic lateral sclerosis (ALS)
- Cancers of the bladder, brain, cervix, colon, esophagus, female breast, kidney, larynx, liver, lung, oral cavity, pancreas, prostate, rectum, and soft tissue
- Hematopoietic cancers
 - Hodgkin's Lymphoma
 - Leukemias
 - Multiple myeloma
 - Non-Hodgkin's lymphoma
- Non-cancerous kidney diseases
- Non-cancerous liver diseases
- Multiple sclerosis
- Parkinson's disease

¹Continuous quarterly information on DOD employment from the Defense Manpower Data Center began with the second quarter of 1973. The most heavily contaminated wells at Camp Lejeune were shut down in 1985.

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The study also included three causes of death known to be caused by cigarette smoking but not known to be associated with the drinking water contaminants: cardiovascular disease, chronic obstructive pulmonary disease (COPD), and stomach cancer. These causes of death were included to assess the possible impact of smoking on the findings because we did not have information on smoking status for study subjects.

Features of this Study

The study looked at the Camp Lejeune civilian workers and a comparison civilian worker population from Camp Pendleton. Camp Pendleton did not have a contaminated drinking water supply.

The cumulative exposure of each Camp Lejeune worker was based on the workplace location, duration of employment, and the monthly average estimates of the contaminants in the drinking water serving the workplace. Monthly contaminant levels in the drinking water were estimated by modeling the movement of the contaminants from the source of pollution through the ground water and into the water distribution system.

Key Results

During 1979-2008, there were 654 deaths in the Camp Lejeune group of civilian workers and 869 deaths in the Camp Pendleton group. The median ages in 2008 for the Camp Lejeune and Camp Pendleton cohorts were 58 years and 60 years, respectively.

Compared with the Camp Pendleton workers, the Camp Lejeune workers had higher mortality rates for the following causes of death:

- Cancers of the female breast, kidney, lung, oral cavity, prostate, and rectum
- Kidney diseases
- Leukemias
- Multiple myeloma
- Parkinson's disease

The higher rates of cancers of the kidney, prostate and rectum, leukemias, and Parkinson's disease were mainly among the Camp Lejeune civilian workers with higher cumulative exposures to the contaminants.

When those with higher exposures at Camp Lejeune were compared to those with lower exposures at Camp Lejeune, higher cumulative exposures to the contaminants were associated with increased risks for cancers of the kidney, esophagus, prostate, and rectum, leukemias, and Parkinson's disease.

The findings for the smoking-related causes of death, such as stomach cancer, cardiovascular disease, and chronic obstructive pulmonary disease suggested that smoking would have only a minor impact on any association between cause of death and exposure to the drinking water contaminants at Camp Lejeune.

Conclusion

The study found elevated risks in the Camp Lejeune civilian workers for several causes of death, including kidney cancer, leukemia's, prostate cancer, rectal cancer and Parkinson's disease. Because only 14% of the Camp Lejeune group had died by the end of the study, the numbers of cause-specific deaths were small, resulting in wide confidence intervals. Wide confidence intervals indicate considerable uncertainty about the actual risk (it could be higher or lower). Note: ATSDR recently published a mortality study of Marines and Navy personnel at Camp Lejeune. Several cancers with elevated risk in that study were also elevated among the civilian employees: cancers of the kidney, prostate, lung and rectum, leukemias, and multiple myeloma: <http://www.atsdr.cdc.gov/sites/lejeune/mortalitystudy.html>.

Camp Lejeune Health Studies

Evaluation of mortality among Marines and Navy personnel exposed to contaminated drinking water at USMC Base Camp Lejeune: A retrospective cohort study

Study Purpose

The purpose of this study was to determine whether residential exposures of Marines and Navy personnel to contaminated drinking water at Camp Lejeune increased risk of mortality from cancers and other chronic diseases.

What Was Studied

The study evaluated specific causes of death in 154,932 Marines and Navy personnel who began service during 1975-1985¹ and were stationed at Camp Lejeune anytime during this period. We also evaluated a comparison group of 154,969 Marines and Navy personnel from Camp Pendleton. The Camp Pendleton group was not exposed to contaminated drinking water, but was otherwise similar to the Camp Lejeune group.

Cause of death data from 1979-2008 was used to study the Camp Lejeune and Camp Pendleton cohorts. Information on causes of death was obtained from the National Center for Health Statistics National Death Index (NDI). The study included all underlying causes of death that other studies have shown associations with one or more of the chemicals found in the drinking water at Camp Lejeune. Causes of death were selected based on literature reviews conducted by the U.S. Environmental Protection Agency (EPA), the National Toxicology Program (NTP), the International Agency for Research on Cancer (IARC), and ATSDR.

The causes of death studied include:

- Amyotrophic lateral sclerosis (ALS)
- Cancers of the bladder, brain, cervix, colon, esophagus, female breast, kidney, larynx, liver, lung, oral cavity, pancreas, prostate, rectum, and soft tissue
- Hematopoietic cancers
 - Hodgkin's Lymphoma
 - Leukemias
 - Multiple myeloma
 - Non-Hodgkin's lymphoma
- Non-cancerous kidney diseases
- Non-cancerous liver diseases
- Multiple sclerosis

¹Unit information with location for marines and navy personnel was not available in the Defense Manpower Data Center personnel database prior to 1975. The most heavily contaminated wells were shut down in 1985.

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Also included in the study were three causes of death that are known to be caused by cigarette smoking but are not known to be associated with the drinking water contaminants: cardiovascular disease, chronic obstructive pulmonary disease (COPD), and stomach cancer. These causes of death were included to assess the possible impact of smoking on the findings because we did not have information on smoking status for study subjects.

Features of this Study

The study included a comparison population from Camp Pendleton that was similar to the Camp Lejeune cohort on risk factors such as military training, occupations, and smoking. Camp Pendleton did not have a contaminated drinking water supply.

Residential cumulative exposure to each contaminant was based on results from the water modeling and the location and duration of residence.

Key Results

Compared to Camp Pendleton, the Camp Lejeune group had higher mortality rates for the following causes of death:

- Cancers of the cervix, esophagus, kidney, liver, lung, pancreas, prostate, rectum, and soft tissue
- Hodgkin's lymphoma
- Leukemias
- Multiple myeloma
- Multiple sclerosis

The higher rates for kidney cancer, cervical cancer, Hodgkin's lymphoma, leukemias, multiple myeloma, and lung cancer were mainly among those with higher cumulative exposures to the contaminants. However, the precision of the estimated rates of many of these conditions was low.

The findings for the smoking-related causes of death such as stomach cancer, cardiovascular disease, and COPD suggested that smoking would have only a slight impact on the associations between causes of death and exposure to the drinking water contaminants at Camp Lejeune.

Conclusion

The study found increased risk of death in the Camp Lejeune cohort for several causes including cancers of the cervix, esophagus, kidney, and liver, Hodgkin's lymphoma, and multiple myeloma. This study makes an important contribution to the body of evidence about harm caused by these chemicals. However, due to its limitations it does not provide definitive evidence for causality nor can it answer the question whether an individual has been affected by these exposures at Camp Lejeune.

Public Summary and Context

Contaminated Water Supplies at Camp Lejeune

Assessing Potential Health Effects

In the early 1980s, two water-supply systems on the Marine Corps Base Camp Lejeune in North Carolina were found to be contaminated with the industrial solvents trichloroethylene (TCE) and perchloroethylene (PCE). The water systems were supplied by the Tarawa Terrace and Hadnot Point water-treatment plants, which served enlisted-family housing, barracks for unmarried service personnel, base administrative offices, schools, and recreational areas. The Hadnot Point water system also served the base hospital and an industrial area and supplied water to housing on the Holcomb Boulevard water system (full-time until 1972 and periodically thereafter).

This report examines what is known about the contamination of the water supplies at Camp Lejeune and whether the contamination can be linked to any adverse health outcomes in former residents and workers at the base. Because of the technical nature of the report, this public summary is being provided to explain the committee's approach

and reasoning, so that people who are not scientists can understand what was done and why. It attempts to place the committee's analysis and findings into the context of a larger discussion about environmental health issues at Camp Lejeune in a way that will be helpful to people who have personal concerns about the situation at the base. It also provides perspective on why the committee was unable to answer some questions.

The Charge to the Committee

The National Research Council (NRC) conducted this review in response to a request from the U.S. Navy, the department under which the Marine Corps operates. The Navy was mandated by the U.S. Congress (Public Law 109-364, Section 318) to request a review by the NRC to address the evidence on whether adverse health outcomes are associated with past contamination of the water supply at Camp Lejeune. The NRC developed specific instructions for the scope of the review ("the charge").

It then recruited and appointed a committee of scientists with diverse but pertinent backgrounds and perspectives to carry out the review.

The charge had several elements. One was to review the scientific evidence about the kinds of adverse health effects that could occur after exposure to TCE, PCE, and other contaminants. The second was to



Courtesy U.S. Marine Corps.

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evaluate studies that were performed or that are under way on former residents of the base and to consider how useful it will be to conduct additional studies. The third element was to identify scientific considerations that could help the Navy set priorities on future activities. The responsibility of the committee was to address its charge in a dispassionate, expert, and unbiased way. Analyses and findings were neither subject to oversight nor influenced by the agenda of any of the entities with responsibilities for Camp Lejeune, former or current residents of Camp Lejeune, or any other entity.

The Concerns of Former Residents and Workers

The committee held three public meetings over the course of its study, two in Washington, DC (September 24, 2007, and September 12, 2008) and one in Camp Lejeune, NC (November 15, 2007). Former residents and other concerned individuals presented oral and written testimonies about their experiences at Camp Lejeune at those meetings. The committee also sought comments from consultants working with community groups seeking answers to questions about the water contamination. Although these encounters were not exhaustive in identifying all issues of concern or all perspectives, they gave the committee a chance to hear firsthand from people who have concerns. The committee sincerely appreciates the time and effort that went into the presentations, testimonies, and materials that were provided.

On the basis of the public input, the committee understands that some people believe that the Marine Corps has not responded appropriately to the contamination since it was first discovered. Some believe that the military leadership has not been fully forthcoming in providing data and information about the contamination and about the people who lived in affected areas. Some have concerns about whether information was disclosed or released in timely and appropriate ways. Questions have also been raised about the pace at which investigations have been conducted and whether the investigations are the most appropriate ones. Many expressed an interest in an unbiased and credible review.

Many of the people who addressed the committee have suffered from serious diseases or have family members or friends who have suffered. The committee was moved by the testimonies it heard and understands that some may have been looking for the committee to make a judgment on their particular

case. However, science does not allow the committee to determine the cause of a specific case of disease. This may be hard to understand. Why would scientific experts not be able to determine whether a child's birth defect or a parent's cancer diagnosis was due to a chemical exposure? Unfortunately, for diseases that can have multiple causes and that develop over a long period of time, it is generally impossible to establish definitively the cause in individual cases. It was beyond the scope of the committee's charge to try to determine whether any particular case of a disease or disorder is associated with exposure to the water supply at Camp Lejeune.

Some parties contend that the Marine Corps has not done what it should to compensate them or to provide medical care for the harm they believe was caused by their exposure to the contaminated water supplies. In 2007, the U.S. Government Accountability Office (GAO) reported that former residents and employees of Camp Lejeune had filed more than 750 claims against the federal government related to the contamination. GAO also reports that the federal government is awaiting the results of a study on childhood cancers and birth defects before adjudicating claims. It was beyond the scope of the committee's charge to judge whether the military authorities acted appropriately from a legal or ethical perspective or fulfilled their responsibilities to those under their charge. It was also beyond the scope of the committee's charge to determine whether or how the military authorities should address claims made.

The Committee's Review and Findings

The committee divided its review into two major categories: (1) evaluating the exposures of former residents and workers to the contamination of the Tarawa Terrace and Hadnot Point water-supply systems, and (2) evaluating the potential health effects associated with the water contaminants. The assessments were then considered together to ascertain whether conclusions could be drawn about whether any adverse health outcomes could be attributed to the water contaminants.

Exposures to Former Residents and Workers

The term "exposure" refers to contact with contaminants in air, water, or food that may occur through inhalation, ingestion, or dermal absorption (through the skin). In this case, it refers to drinking water that contains contaminants or using it for other purposes. Bathing and showering are relevant, as well

as drinking, because TCE and PCE (and other solvents) can evaporate into the air (volatilize) when present in hot water used for bathing, showering, or washing dishes or clothing and can then be inhaled. All of these routes of exposure affect how the body metabolizes TCE and PCE, how the metabolites are distributed and cleared by the body, and how organ systems respond.

It is also important to understand the duration of exposure, which is the length of time a person is exposed. An understanding of individual behaviors helps to estimate the degree of exposure that occurred. Water-related behaviors include water-consumption and showering or bathing patterns, but whether such information can be accurately recalled is questionable. The contaminated water systems also supplied nonresidential areas of the base, including schools, workplaces, recreational areas, and a hospital. Water-use patterns and behaviors in these settings are expected to vary substantially from those in residential

areas. In addition, residential and nonresidential exposures could overlap, thus, exposing individuals to contaminated water at multiple locations.

The Water Systems at Camp Lejeune

Figure 1 provides a simplified illustration of a water-supply system at Camp Lejeune. Water-supply wells collected groundwater and pumped it to a water-treatment plant when the wells were turned on. The wells were “cycled,” meaning that only a few wells pumped water to the treatment plant at any given time. A few wells that supplied water to the Tarawa Terrace and Hadnot Point systems were contaminated by solvents from sources on and off the base. When the contaminated wells were in service, contaminated water was delivered to the water-treatment plant where water from several wells was mixed and processed before being distributed in the pipes that supplied water to the base. Thus, the contamination of the water supplies varied and was

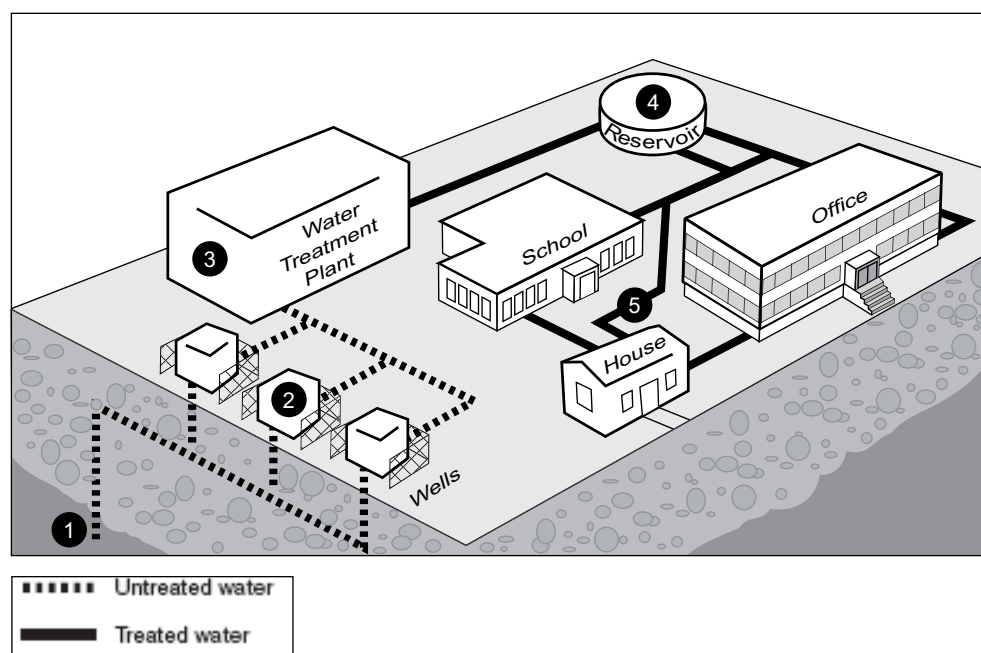


FIGURE 1 Conceptual model of a Camp Lejeune water system. (1) The drinking water at Camp Lejeune is obtained from groundwater pumped from a freshwater aquifer located approximately 180 feet below the ground. (2) Groundwater is pumped through wells located near the water-treatment plant. (3) In the water-treatment plant, the untreated water is mixed and treated through several processes: removal of minerals to soften the water, filtration through layers of sand and carbon to remove particles, chlorination to protect against microbial contamination, and fluoride addition to help to prevent tooth decay. (4) After the water is treated, it is stored in ground and elevated storage reservoirs. (5) When needed, treated water is pumped from the reservoirs and tanks to facilities such as offices, schools, or houses on the base. Source: GAO. 2007. Defense Health Care: Activities Related to Past Drinking Water Contamination at Marine Corps Base Camp Lejeune. GAO-07-276. Washington, DC: U.S. Government Accountability Office.

dependent on many factors, such as the time of operation of the contaminated wells, the water treatments used, and the rate at which water was supplied to the base.

Exposure Review

The committee's exposure evaluation involved identifying the contaminants of concern, their sources, and the concentrations estimated to be present in the water supplies over time. For Tarawa Terrace, the committee relied on work by the Agency for Toxic Substances and Disease Registry (ATSDR). ATSDR compiled the available information on the Tarawa Terrace water system and used computer models to simulate how contaminants moved underground, entered water-supply wells, and were distributed in the water supply. Contaminant measurements were only available from 1980 to 1985, so models were needed to make estimates of the concentrations of contaminants in the water supply in the preceding decades.

A similar historical reconstruction has not yet been performed for the Hadnot Point water system. To identify contaminants of concern there, the committee reviewed information on historical activities on the base (for example, building and chemical uses and sites of hazardous-waste storage or disposal) and findings from site investigations and plans for remedial action at waste sites. The committee also reviewed data available from testing records and other documents to get a preliminary characterization of the exposures that occurred. For some of its analyses, the committee focused on samples taken from "mixed water," that is, water mixed from several supply wells at the treatment plant, because those measurements were probably the most representative of the contaminant concentrations that were delivered to the taps on base. As was the case with Tarawa Terrace, contaminant measurements of the Hadnot Point system were only available from 1980 to 1985.

The major contaminants of the Tarawa Terrace and Hadnot Point systems are of a particular form that tends to serve as a continuing source of contamination even after the contaminants are underground. These are called "DNAPLs," which stands for dense nonaqueous phase liquids. DNAPLs are dense, so they have the potential to sink into the deeper aquifers. Such chemicals get trapped in the soil and dissolve slowly into groundwater. The geology of the area makes it probable that DNAPLs that were spilled on the ground or that were leaked or disposed of in

the soil got into the groundwater that supplied some of the wells of the two systems.

The dry-cleaning solvent PCE is the primary contaminant of the Tarawa Terrace water-supply system. Spills and improper disposal of PCE by an off-base dry-cleaner contaminated the groundwater collected by on-base supply wells. Other contaminants detected in water-supply wells were TCE, 1,1-dichloroethylene (DCE), *cis*-1,2-DCE, *trans*-1,2-DCE, benzene, toluene, and vinyl chloride. Several of the contaminants (TCE, *cis*-1,2-DCE, *trans*-1,2-DCE, and vinyl chloride) may be the result of degradation of PCE in the soil and groundwater. There was some on-base contamination of the Tarawa Terrace supply system as well.

Sophisticated computer modeling techniques were used by ATSDR to make predictions about the monthly concentrations of PCE to which residents of Tarawa Terrace were exposed. To provide perspective on its estimates, ATSDR compared its monthly estimates with the U.S. Environmental Protection Agency (EPA) maximum contaminant level (MCL) for PCE in drinking water of 5 µg/L, which was established in 1985. The model estimated that starting in November 1957, the concentration of PCE delivered to residents exceeded that MCL and remained well above it until the wells were closed in 1985.

Some of the modeling approaches used by ATSDR were "cutting-edge," meaning that they used computer codes and modeling techniques that are still in the research stage and have yet to be validated. Furthermore, the absence of measurement data for the first 30 years of the contamination period means the predictions, even if based on validated codes and models, cannot be evaluated for accuracy. The actual concentrations may have been higher or lower than the predictions, but that cannot be assessed. Other uncertainties were introduced into the models because assumptions had to be made about how the water system was operating. For example, little information was available on which wells were supplying water at specific time periods, so assumptions had to be made about when the contaminated wells were operating. Another uncertainty is that the models did not take into account the DNAPL form of pollutants. Given the multiple uncertainties and likely variation in contaminant concentrations, the committee concluded that the Tarawa Terrace modeling predictions should only be used to provide a general estimate of the timeframe and magnitude of exposure.

The contamination of the Hadnot Point system was more complex than Tarawa Terrace. There were multiple sources of pollutants, including an industrial area, a drum dump, a transformer storage lot, an industrial fly ash dump, an open storage pit, a former fire training area, a site of a former on-base dry cleaner, a liquids disposal area, a former burn dump, a fuel-tank sludge area, and the site of the original base dump. The available data on contaminant measurements taken in the 1980s show that TCE and *trans*-1,2-DCE were the contaminants found most often in mixed-water samples, with a few detections of PCE, methylene chloride, and vinyl chloride. The nature of the hazardous-waste sites in the vicinity of the Hadnot Point supply wells suggests that other contaminants may have been present. For example, tests of samples taken from special monitoring wells installed after the contamination was discovered have detected fuel constituents and metals, compounds that were not routinely analyzed in the water samples taken in the 1980s.

Recommendations

- For the purposes of epidemiologic studies, the results of the Tarawa Terrace historical reconstruction can be used to characterize people as being exposed or unexposed on the basis of date and location of residence or workplace. The monthly estimates imply more accuracy than is appropriate and should not be used to characterize exposure of individual people.
- Because any groundwater modeling of the Hadnot Point system will be fraught with considerable difficulties and uncertainties, simpler modeling approaches should be used to assess exposures from the Hadnot Point water system. Simpler modeling will not reduce the uncertainty associated with the estimates, but they have the advantage of providing a broad picture of the timeframe and magnitude of exposure encountered by people who used water from that system more quickly and with less resources than complex modeling exercises.
- To facilitate better understanding of the contamination on the base, the Marine Corps should develop a comprehensive and accessible database of water-quality measurements taken from the base.



Photo by Bruce Muhlenberg.

Potential Health Effects

The committee undertook four kinds of reviews to determine what kinds of diseases or disorders (adverse health effects) have been found to result from exposure to TCE and PCE: (1) review of epidemiologic studies of solvents and their effects, including studies in occupational and industrial settings and community studies; (2) review of epidemiologic studies of other communities with solvent-contaminated water supplies; (3) review of toxicologic studies conducted in animals and humans to test for health effects of TCE and PCE; and (4) review of studies conducted specifically on the Camp Lejeune population.

Review of Epidemiologic Evidence on Solvents

Epidemiologic studies examine whether people with greater exposure to particular chemicals have greater frequency of disease than people with lesser or no exposure (also referred to as greater incidence or greater risk of disease). To manage the review of the vast amount of peer-reviewed scientific literature on TCE and PCE, the committee began with a comprehensive review of the epidemiologic studies of those solvents that was conducted by the Institute of Medicine (IOM) in 2003. IOM categorized the evidence according to an established scheme accepted by the Department of Veteran's Affairs in evaluating risks to veterans of the Vietnam War and the Gulf War. These categories are shown in Box 1. The committee identified new studies published from

BOX 1—Five Categories Used by IOM to Classify Associations

Sufficient Evidence of a Causal Relationship

Evidence from available studies is sufficient to conclude that a causal relationship exists between exposure to a specific agent and a specific health outcome in humans, and the evidence is supported by experimental data. The evidence fulfills the guidelines for sufficient evidence of an association (below) and satisfies several of the guidelines used to assess causality: strength of association, dose-response relationship, consistency of association, biologic plausibility, and a temporal relationship.

Sufficient Evidence of an Association

Evidence from available studies is sufficient to conclude that there is a positive association. A consistent positive association has been observed between exposure to a specific agent and a specific health outcome in human studies in which chance and bias, including confounding, could be ruled out with reasonable confidence. For example, several high-quality studies report consistent positive associations, and the studies are sufficiently free of bias, including adequate control for confounding.

Limited/Suggestive Evidence of an Association

Evidence from available studies suggests an association between exposure to a specific agent and a specific health outcome in human studies, but the body of evidence is limited by the inability to rule out chance and bias, including confounding, with confidence. For example, at least one high-quality study reports a positive association that is sufficiently free of bias, including adequate control for confounding. Other corroborating studies provide support for the association, but they were not sufficiently free of bias, including confounding. Alternatively, several studies of less quality show consistent positive associations, and the results are probably not due to bias, including confounding.

Inadequate/Insufficient Evidence to Determine Whether an Association Exists

Evidence from available studies is of insufficient quantity, quality, or consistency to permit a conclusion regarding the existence of an association between exposure to a specific agent and a specific health outcome in humans.

Limited/Suggestive Evidence of No Association

Evidence from well-conducted studies is consistent in not showing a positive association between exposure to a specific agent and a specific health outcome after exposure of any magnitude. A conclusion of no association is inevitably limited to the conditions, magnitudes of exposure, and length of observation in the available studies. The possibility of a very small increase in risk after exposure studied cannot be excluded.

Source: IOM (Institute of Medicine). 2003. Gulf War and Health, Vol. 2, Insecticides and Solvents. Washington, DC: National Academies Press.

2003 to 2008 and considered whether they changed the conclusions in the IOM report. The studies included people exposed in occupational situations and in community settings.

IOM's approach to evaluating the literature is to determine whether a "statistical association" exists between the chemicals and diseases and disorders. When studies are conducted properly, a statistical association means that people who are exposed to the chemicals are more likely to have or develop the disease or disorder than people who are not exposed. A statistical association, however, does not establish that the chemicals cause the diseases or disorders.

Judgment about the quality of each study and additional supporting evidence from other studies are needed. Statistical associations are often represented by numeric estimates, known as "relative risks" or "odds ratios." The estimates describe the relative frequency of disease in groups with higher exposures compared with groups with lower or no exposure. For example, in a study in which individuals are classified as either exposed or unexposed, a relative risk of 2 means that exposed people in the study were twice as likely to develop the disease as people who were not exposed.

As shown in Box 2, all the health outcomes reviewed were placed into one of two categories.

BOX 2—Categorization of Health Outcomes^a Reviewed in Relation to TCE, PCE, or Solvent Mixtures

Sufficient Evidence of a Causal Relationship

- No outcomes

Sufficient Evidence of an Association

- No outcomes

Limited/Suggestive Evidence of an Association

- | | |
|--|---|
| <ul style="list-style-type: none"> • Esophageal cancer (PCE) • Lung cancer (PCE) • Breast cancer (PCE) • Bladder cancer (PCE) • Kidney cancer • Adult leukemia (solvent mixtures) • Multiple myeloma (solvent mixtures) • Myelodysplastic syndromes (solvent mixtures) | <ul style="list-style-type: none"> • Renal toxicity (solvent mixtures) • Hepatic steatosis (solvent mixtures) • Female infertility (with concurrent exposure to solvent mixtures) • Miscarriage (with exposure to PCE during pregnancy) • Scleroderma (solvent mixtures) • Neurobehavioral effects (solvent mixtures) |
|--|---|

Inadequate/Insufficient Evidence to Determine Whether an Association Exists

- | | |
|--|---|
| <ul style="list-style-type: none"> • Oral/pharyngeal cancer • Nasal cancer • Laryngeal cancer • Esophageal cancer (TCE) • Stomach cancer • Colon cancer • Rectal cancer • Pancreatic cancer • Hepatobiliary cancer • Lung cancer (TCE) • Bone cancer • Soft tissue sarcoma • Melanoma • Non-melanoma skin cancer • Breast cancer (TCE) • Cervical cancer • Ovarian/uterine cancer • Prostate cancer • Bladder cancer (TCE) • Cancer of the brain or central nervous system • Non-Hodkin lymphoma • Hodgkin disease • Multiple myeloma • Adult leukemia | <ul style="list-style-type: none"> • Myelodysplastic syndromes • Childhood leukemia • Childhood neuroblastoma • Childhood brain cancer • Aplastic anemia • Congenital malformations • Male infertility • Female infertility (after exposure cessation) • Miscarriage, preterm birth, or fetal growth restriction (from maternal preconception exposure or paternal exposure) • Preterm birth or fetal growth restriction (from exposure during pregnancy) • Cardiovascular effects • Liver function or risk of cirrhosis • Gastrointestinal effects • Renal toxicity • Amyotrophic lateral sclerosis • Parkinson disease • Multiple sclerosis • Alzheimer disease • Long-term reduction in color discrimination • Long-term hearing loss • Long-term reduction in olfactory function |
|--|---|

Limited/Suggestive Evidence of No Association

- No outcomes

^aOutcomes for TCE and PCE unless otherwise specified.

The strongest evidence was in the category of *limited/suggestive of an association*, which means that there is some evidence that people who were exposed to TCE or PCE were more likely to have the disease or disorder but that the studies were either few in number or had important limitations. In many cases, the studies could not separate out the effects of individual chemicals because the people were exposed to mixtures. Some of these studies were of highly exposed groups of workers where detection of effects would be expected if present. Such studies might reach conclusions about solvents in general but not about TCE or PCE specifically. For diseases and disorders where the evidence is limited/suggestive of an association, the committee has concluded that the epidemiologic studies give some reason to be concerned that sufficiently high levels of the chemical may cause the disease, but the studies do not provide strong evidence that they actually do so.

The majority of the health outcomes reviewed by the committee were placed into the category of *inadequate/insufficient evidence to determine whether an association exists*, which means that the studies were too few in number, limited in quality, inconsistent, or inconclusive in results to make an informed assessment. It also means that such an association cannot be ruled out. For diseases and disorders in this category, the committee has concluded that the epidemiologic studies cannot tell us whether exposure to the chemicals is associated with the disease or not.

The committee is aware that some health outcomes reported by former residents of the base (for example, male breast cancer and second-generation effects) are not cited in Box 2. The absence of inclusion of specific health outcomes does not mean that such effects are unrelated to exposures from the contaminated water supplies at Camp Lejeune. Rather, those outcomes have not been specifically investigated or, if they were considered, the studies were too small or of insufficient quality to allow conclusions to be drawn.

Review of Epidemiologic Evidence from Community Studies

The committee decided to consider the subset of epidemiologic studies that were conducted in communities exposed to solvents in their water supplies in more detail. Because these studies involved populations and exposure situations that more closely resemble those at Camp Lejeune, some relevant

implications might be learned. A few studies reported certain diseases and disorders, such as congenital heart defects, spontaneous abortions, and very low birth weight. However, the studies reported differing effects, so generally they did not confirm each other. In general, the studies had limitations in their design that are unavoidable because of the circumstances that gave rise to them. The limitations include lack of data on levels of contaminants in the water, lack of adequate information about diseases and disorders in the population, and relatively small populations. These factors limit the capacity of such studies to detect associations even if they exist. Limitations in such studies often mean that people in the study communities can only be classified into two groups to reflect exposure to contamination—those exposed and those considered unexposed. Such classification is a crude way to address exposure because it can make it more difficult to detect any effects that might occur. Another common limitation of community studies in general is that they are not able to account for other factors that may affect the likelihood of disease. Furthermore, the studies face the difficult task of addressing diseases that are relatively uncommon. It is harder to find enough cases of uncommon diseases to make comparisons when studying relatively small populations. The committee concluded that the evidence provided by this subset of epidemiologic studies needs further support and confirmation before they can be considered significant on their own.

Review of the Toxicologic Evidence

Toxicologic studies are mainly laboratory experiments, usually conducted on animals. The committee's review on TCE and PCE were in part based on previously published toxicologic reviews but were mainly based on analyses of recently published studies. The studies were analyzed using criteria for good study design and degree of agreement between the conclusions and the data presented. Further, the committee took into consideration the quality and reliability of studies, consistency of findings of similar studies, understanding of the biologic processes, toxicologic significance, dose- and duration-dependence, and understanding of whether effects observed in animals are predictive of human risks. Each chemical was reviewed for effects on the major organ systems—for example, liver, kidneys, lungs, reproductive system, nervous system, and immune system.

In animal experiments, TCE was reported to cause kidney and testicular cancers in rats and liver and lung cancers in mice. PCE was reported to cause

liver cancer in mice and mononuclear cell leukemia and kidney cancer in rats. Differences in how these chemicals are handled in the body by rodents and humans, as well as current scientific understanding of how these tumors develop, led the committee to the conclusion that kidney cancer is the most relevant to humans.

For other kinds of adverse health effects, kidney toxicity and liver toxicity were observed in rodents given high doses of TCE and PCE. Effects on male rodent fertility, but not female fertility, were observed. Neither chemical caused birth defects in rats. There were some adverse effects on offspring of pregnant female rats exposed to PCE but to not TCE. Adverse changes in some nervous system measurements were seen in some TCE and PCE studies. TCE causes some effects on the immune system of sensitive strains of mice, but there are few immunotoxicity studies on PCE.

When possible, the committee identified the lowest dose of TCE or PCE at which adverse effects were observed in animal studies (the dose is called the lowest-observed-adverse-effect level or LOAEL). To put these doses in perspective, the committee did a comparison of the doses with approximated doses to former residents that were estimated from concentrations of TCE and PCE measured in mixed water.¹ Because of the known variation in contaminant concentrations, the range used for the comparison included the highest measured concentrations of TCE and PCE in mixed water, one-half those concentrations, and twice the highest measured concentrations. The adverse health effects considered for this comparison were those thought to be most relevant to humans (kidney cancer, renal toxicity, and immunosuppression for TCE, and renal toxicity and neurotoxicity for PCE). This comparison is not an assessment or prediction of risk and can only give a general indication of the degree of difference between doses that caused a response in laboratory animals and doses to former residents of Camp Lejeune. The comparison reflects estimated combined daily doses from all three routes of exposure (ingestion, inhalation, and skin contact) that could have occurred for adults and children at Camp Lejeune. Results of the comparison suggest that the highest levels of either TCE or PCE measured in the mixed-water samples at Camp Lejeune were much lower than the lowest dose that caused adverse

effects in the most sensitive strains and species of laboratory animals. The lower levels of exposure may be of some concern for effects on neurotoxicity and immunotoxicity, but further research is needed to evaluate the specific effects of TCE and PCE and whether they are relevant to humans.

Consideration of the Epidemiologic and Toxicologic Evidence Together

The committee considered collectively what is known about adverse health effects that are associated with exposure to TCE and PCE from human epidemiologic and animal toxicologic studies. Evidence on similar outcomes reported in animal and human studies were compared to see whether the data were supportive of the potential health consequences of exposure to TCE and PCE in the water supply.

Review of epidemiologic studies on cancer outcomes provided limited/suggestive evidence for an association between chronic exposure to TCE or PCE and kidney cancer and to PCE and cancers of the esophagus, lungs, breast, and bladder. For these outcomes, the toxicologic evidence was strongest for kidney cancer.

Noncancer effects that were found to be similar in humans and laboratory animals included adverse effects on the liver, kidneys, and nervous and immune systems. In the epidemiologic literature, toxic effects on the liver and kidneys appeared to be related to short-term inhalation of high concentrations of solvents as opposed to longer-term exposure at lower concentrations. Support for these effects observed in toxicologic studies come from rodents exposed to high concentrations of TCE and PCE. For kidney effects, adverse findings were only found in male rats. Epidemiologic studies of occupational exposure to mixed solvents showed limited/suggestive evidence of neurobehavioral effects, and toxicologic studies of TCE showed some decrements in neurobehavioral outcomes. For effects on the immune system, epidemiologic studies showed limited/suggestive evidence for an association with mixed solvent exposure for certain immunologically mediated diseases. Toxicologic studies also showed that TCE can affect the immune system, as shown by immunosuppression and worsening of preexisting autoimmune diseases. These findings are shown in Table 1. The absence of other diseases and disorders in the table does not mean that such outcomes are irrelevant or unworthy of study, but that the findings for them were inconsistent between the toxicologic and the epidemiologic evidence or were not addressed in the available studies.

¹ A dissenting viewpoint from one committee member on this evaluation is provided in Chapter 4.

Review of Camp Lejeune Studies

Only a few studies have been conducted on the Camp Lejeune population, and these have focused on health effects in people who were exposed as children or while their mothers were pregnant with them. One study evaluated pregnancy outcomes among women who lived in base housing from 1968 to 1985.

Although the water contamination probably began before 1968, ATSDR selected 1968 as its starting point because electronic birth certificates became available that year. ATSDR compared data on premature births, births of babies who were small relative to other babies from pregnancies of similar duration (small for gestational age), and birth weights between mothers who were exposed and those who were unexposed. Whether mothers were exposed was determined by where they lived on the base when the child was born, not taking into account whether they moved during the pregnancy. Two analyses were performed; one that evaluated residents of Hadnot Point and Tarawa Terrace and one that focused only on Tarawa Terrace residents.

In both analyses, no clear associations were found between mean birth weight, preterm birth, or small for gestational age. However, a comparison of sub-groups within the Tarawa Terrace population found a weak association between PCE exposure and small-for-gestational-age births for children of women over 35 or of women who had prior miscarriages. However, a limitation of this conclusion is that the decision to perform this analysis was added after the original

design of the study. It was not one of the hypotheses or theories set out before the study. Therefore, scientists give this finding less weight.

The findings from these analyses are no longer valid. After the study was completed, ATSDR discovered that a residential area it classified as unexposed (Holcomb Boulevard) received water from the Hadnot Point system for the first 4 years of the study period, and the study results must be reanalyzed to correct for this mistake in classification. ATSDR has indicated that it will reanalyze the results of the study using exposure estimates from its groundwater modeling of the Tarawa Terrace and Hadnot Point systems.

ATSDR also has a study under way on prenatal exposure to water-supply contaminants and birth defects and childhood cancer. The specific outcomes being studied are childhood leukemia, childhood non-Hodgkin lymphoma, spina bifida, anencephaly, cleft lip, and cleft palate. These outcomes are rare, and given the number of study participants, it appears that the statistical power of this study could limit its ability to detect associations. The study is also awaiting the completion of groundwater modeling of the Hadnot Point water system so that differences in exposure can be assessed.

Recommendations

- The committee recommends that ATSDR go forward with reanalyzing its study of birth

TABLE 1 Similar Health Effects Found in Epidemiologic and Toxicologic Studies

Effects	Epidemiologic Evidence	Toxicologic Evidence
Kidney cancer	Limited/suggestive for TCE and PCE	TCE and PCE (limited to male rats)
Liver toxicity	Limited/suggestive for solvents and hepatic steatosis ^a	TCE and PCE (liver damage)
Kidney toxicity	Limited/suggestive for solvents	TCE and PCE (limited to male rats)
Neurobehavioral effects	Limited/suggestive for solvents (effects on visuomotor and motor function, fatigue, headache, deficits in concentration)	TCE: central nervous system depression, attention deficits, deficits in visual discrimination, altered visual evoked potentials ^b PCE: anesthetic effects; changes in behavior and neurochemical markers
Immunologic effects	Limited/suggestive for solvents and glomerulonephritis ^c and scleroderma ^d	TCE: sensitization, immunosuppression, influence autoimmune disease (in sensitive strains of mice)

^a Hepatic steatosis is fatty accumulation in the liver.

^b Electrical response recorded by a skull electrode after a visual stimulus (e.g., a flash).

^c Glomerulonephritis is a disease that affects kidney function.

^d Scleroderma is a disease resulting in abnormal growth of connective tissue.

outcomes to correct for errors in exposure classification without awaiting the results of groundwater modeling of the Hadnot Point system. For the reasons given earlier, such modeling is unlikely to yield reliable quantitative estimates of exposure that would refine exposure classification for epidemiologic study.

- Despite the committee's concerns about the statistical power of the study of birth defects and childhood cancer, it recommends that the study be completed as soon as possible. Simpler approaches to groundwater modeling should be performed to support the exposure classification in the study rather than performing the same type of complex groundwater modeling that was performed for Tarawa Terrace.

The Feasibility and Utility of Future Studies of the Camp Lejeune Population

ATSDR has evaluated the feasibility of conducting three additional studies of the Camp Lejeune population, including a health survey and studies that would evaluate deaths from all causes and cancer incidence among former residents and workers. ATSDR identified some of the same diseases and disorders identified in the committee's review as being of interest. These included kidney cancer, lung cancer, breast cancer, scleroderma, liver disease, kidney disease, and spontaneous abortion. ATSDR also identified additional outcomes of possible interest for its study.

Difficulties with performing the studies are identifying, locating, and recruiting the study participants and obtaining reliable health information on them in an efficient manner. The committee found that although ATSDR did consider the major issues bearing on the feasibility of the proposed studies and proposed reasonable approaches to conducting the studies, there remain serious, unresolved questions about the feasibility and ultimate value of the studies. For example, it is not clear that the cancer incidence study could be performed successfully, because it is contingent on the cooperation of many state cancer registries. Even with cooperation, the statistical power to compare groups of interest across the range of outcomes has yet to be assessed. Statistical power is also an issue with the mortality study.

The committee also reviewed ATSDR's plans for a health survey that was generated in response to a congressional directive. The survey would seek information on residential history and various health

outcomes. Although the survey could contribute to designing future studies at Camp Lejeune, its success depends on getting adequate participation (at least 60%). Even if satisfactory participation is achieved, there are concerns that there could be bias in the reported data because people who have experienced disease or illness are more likely to participate in the survey.

After reviewing the study plans and feasibility assessments, the committee concluded that most questions about whether exposures at Camp Lejeune resulted in adverse health effects cannot be answered definitively with further scientific study. There are two main reasons for this. First, it is not possible to reliably estimate the historical exposures experienced by people at the base. Second, it will be difficult to detect any increases in the rate of diseases or disorders in the study population. Most of the health effects of concern are relatively rare, which means that very large numbers of people are needed to detect increased cases. Although the total number of people who have lived at Camp Lejeune while the Tarawa Terrace and Hadnot Point water supplies were contaminated is sizable, the population is still unlikely to be large enough to detect effects, other than common diseases or disorders, of concern. Another factor is that the population was relatively young, so many who would be studied are in an age range in which chronic diseases are rare. Yet another factor is that the people tended to live on the base for a relatively short time, resulting in a small increase in risk of disease at most, making it difficult to rule out other exposures or factors that could have contributed to disease or illness. All these factors make it unlikely that the proposed studies, even if the notable uncertainties about feasibility are resolved favorably, will produce results of sufficient certainty to resolve the question of whether Camp Lejeune residents suffered adverse health effects from exposure to contaminated water.

The available scientific information does not provide a sufficient basis for determining whether the population at Camp Lejeune has, in fact, suffered adverse health effects as a result of exposure to contaminants in the water supplies. On the one hand, several lines of scientific reasoning suggest such effects are unlikely to have occurred. The evidence includes a substantial body of research on the toxicology of TCE and PCE that indicates that the exposures required to cause adverse effects in laboratory animals were much larger than the highest

measurements available on the Camp Lejeune water supplies; evidence that humans have lower sensitivity to TCE and PCE than rodents; epidemiologic data largely from occupational settings with higher, longer-term exposures to TCE and PCE that has not generated compelling evidence of adverse health effects; and the relatively short-term, intermittent nature of the exposures incurred at Camp Lejeune. On the other hand, the possibility that health effects have been produced by the contaminant exposures at Camp Lejeune cannot be ruled out. Some effects of TCE or PCE exposure might have occurred below the level of detection in toxicologic studies, which focused on single contaminant exposures at high doses, used genetically homogeneous animal strains, and necessarily involved extrapolation across species. In addition, the population exposed at Camp Lejeune is more diverse and possibly more susceptible than those who have been exposed to TCE and PCE in occupational settings, and the actual concentrations of PCE and TCE and the presence of additional water contaminants are poorly documented and could thus be higher or more complex than the limited historical measurements suggest. There were

divergent views among the committee members about the probability that each would assign to whether adverse health effects have in fact occurred, but there was consensus among them that scientific research is unable to provide more definitive answers to that question.

Conclusion and Recommendation

It cannot be determined reliably whether diseases and disorders experienced by former residents and workers at Camp Lejeune are associated with their exposure to contaminants in the water supply because of data shortcomings and methodological limitations, and these limitations cannot be overcome with additional study. Thus, the committee concludes that there is no scientific justification for the Navy and Marine Corps to wait for the results of additional health studies before making decisions about how to follow up on the evident solvent exposures on the base and their possible health consequences. The services should undertake the assessments they deem appropriate to determine how to respond in light of the available information.

Committee on Contaminated Drinking Water at Camp Lejeune: David A. Savitz (Chair), Mount Sinai School of Medicine; Caroline L. Baier-Anderson, Environmental Defense Fund; James V. Bruckner, University of Georgia; Prabhakar Clement, Auburn University; Carole A. Kimmel, Independent Consultant; Francine Laden, Harvard School of Public Health; Bruce P. Lanphear, Simon Fraser University; Xiaomei Ma, Yale University School of Medicine; John R. Nuckols, Colorado State University; Andrew F. Olshan, The University of North Carolina at Chapel Hill; Lianne Sheppard, University of Washington School of Public Health; Elaine Symanski, University of Texas School of Public Health; Janice W. Yager, The University of New Mexico; Susan Martel (*Study Director*), National Research Council.

The National Academies appointed the above committee of experts to address the specific task requested by the U.S. Navy. The members volunteered their time for this activity; their report is peer-reviewed and signed off by both the committee members and the National Academies.



For more information, contact the Board on Environmental Science and Technology at (202) 334-3060 or visit <http://nationalacademies.org/best>. *Copies of Contaminated Water Supplies at Camp Lejeune—Assessing Potential Health Effects* are available from the National Academies Press, 500 Fifth Street, NW, Washington, D.C. 20001; (800) 624-6242; www.nap.edu.

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What You Need to Know

- Taking care of Marines, Sailors, their families, and civilian workers is our top priority.
- The drinking water at Camp Lejeune currently meets or exceeds all federal and state laws and regulations and is tested more often than required.
- The Marine Corps and the Navy are good stewards of the environment and remain committed to restoring and protecting the environment at Camp Lejeune and other installations.
- The Marine Corps continues to work with leading scientific organizations in an effort to provide comprehensive science-based answers to the health questions that have been raised.
- The Marine Corps continues its efforts to identify and notify those who lived or worked at Camp Lejeune in 1987 or before, and will continue to provide them with updates regarding the latest scientific and medical findings.
- The “Honoring America’s Veterans and Caring for Camp Lejeune Families Act of 2012” authorizes the Department of Veterans Affairs to provide health benefits for 15 illnesses or conditions affecting veterans and their families who lived or worked at Camp Lejeune in North Carolina for at least 30 days between January 1, 1957 and December 31, 1987.
- The Department of Veterans Affairs (VA) finalized a new rule on January 13, 2017 to consider eight diseases as presumptive for service connection. This presumptive service connection provides VA disability benefits to veterans who have one of eight diseases and served for no less than 30 days (consecutive or nonconsecutive) on permanent or temporary duty at Camp Lejeune between August 1, 1953 and December 31, 1987.
- To register or to update your registration information, please contact our Call Center at (877) 261-9782.

Website Links of Interest

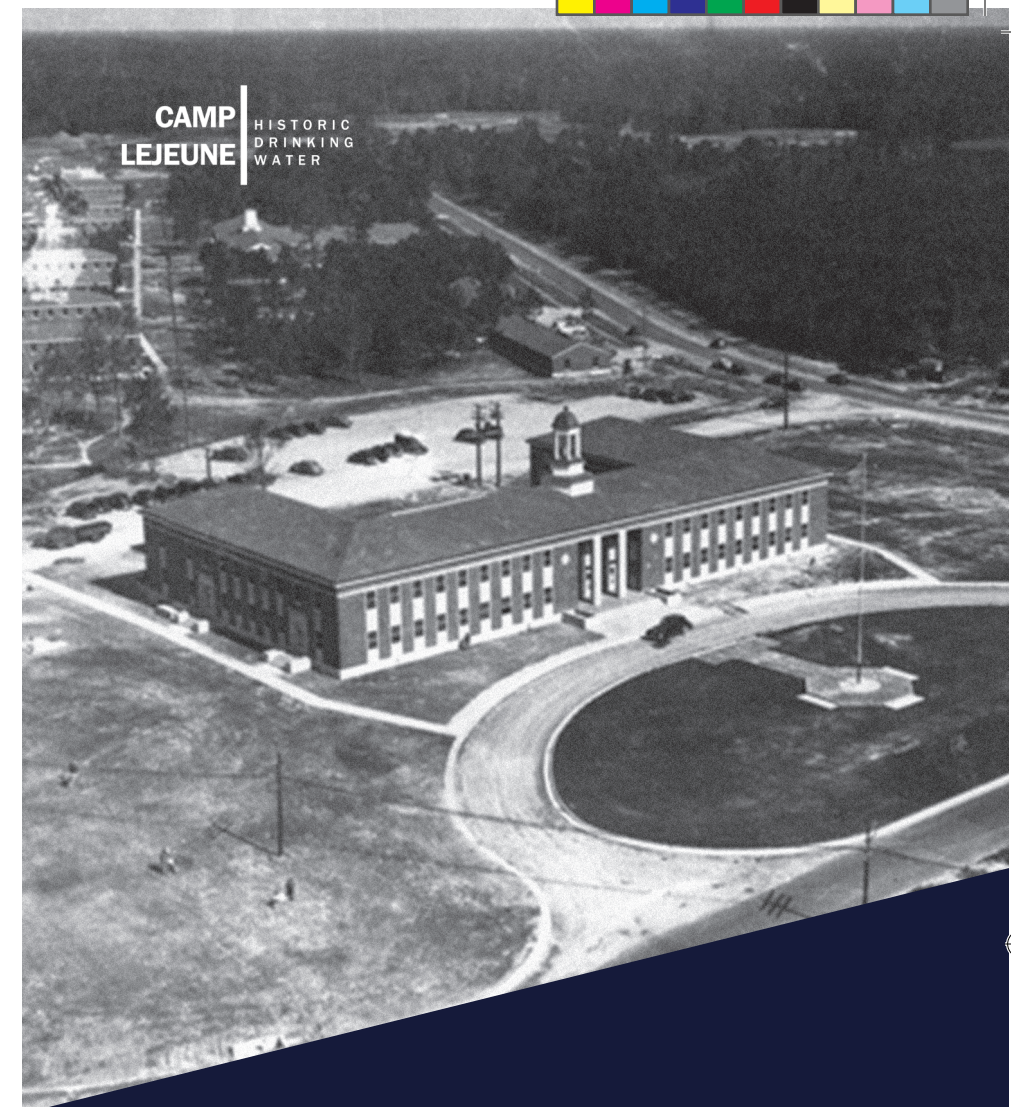
Camp Lejeune Historic Drinking Water Website:
www.marines.mil/clwater

Department of Veterans Affairs:
www.publichealth.va.gov/exposures/camp-lejeune

Agency for Toxic Substances and Disease Registry:
www.atsdr.cdc.gov/sites/lejeune

National Research Council of the National Academies Camp Lejeune Report:
http://dels.nas.edu/resources/static-assets/materials-based-on-reports/reports-in-brief/camp_lejeune_final.pdf

MCBCL EMD’s Water Quality Reports:
www.lejeune.marines.mil/OfficesStaff/EnvironmentalMgmt/AnnualReports.aspx



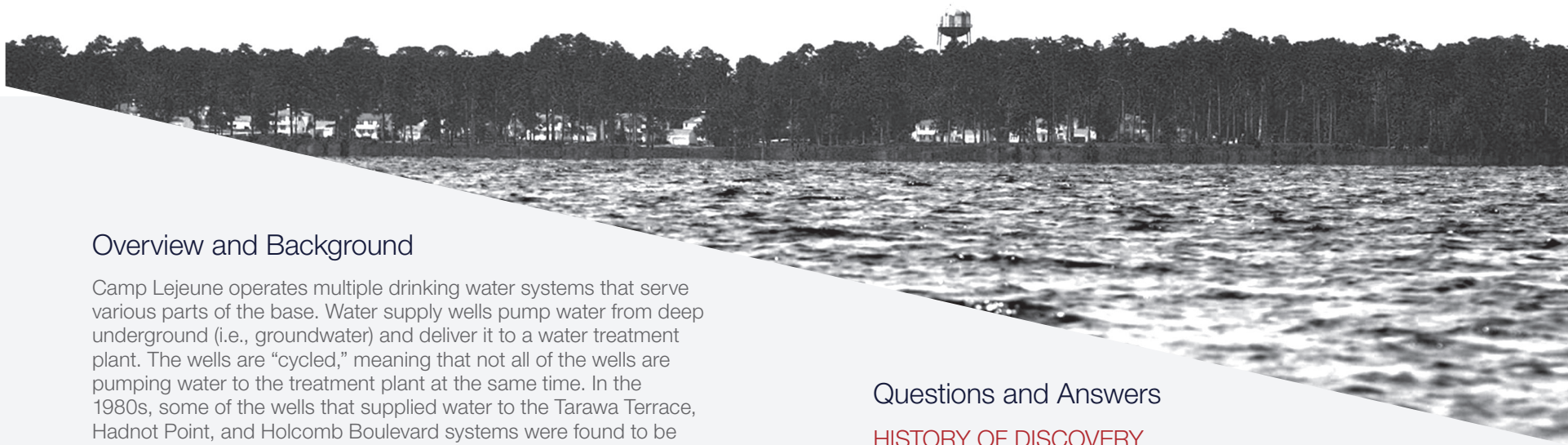
Camp Lejeune Historic Drinking Water



www.marines.mil/clwater

Toll Free Call Center (877) 261-9782
Hours: M-F 8:30 a.m.–5:00 p.m. ET
www.marines.mil/clwater





Overview and Background

Camp Lejeune operates multiple drinking water systems that serve various parts of the base. Water supply wells pump water from deep underground (i.e., groundwater) and deliver it to a water treatment plant. The wells are “cycled,” meaning that not all of the wells are pumping water to the treatment plant at the same time. In the 1980s, some of the wells that supplied water to the Tarawa Terrace, Hadnot Point, and Holcomb Boulevard systems were found to be affected by chemicals. In 1982, special tap water testing identified trichloroethylene (TCE) and tetrachloroethylene (PCE). The test results varied between drinking water samples collected at different times. In 1984-1985, when base officials discovered that these chemicals were in specific drinking water supply wells, these affected wells were taken out of service. The chemicals detected in the drinking water were a class of chemicals known as “volatile organic compounds.” These chemicals are commonly used as solvents for cleaning machinery and weapons, for dry cleaning, and some are found in fuels. The chemicals were later identified as coming from both on-base sources and an off-base source.



While the affected wells were in service, well water was delivered to the water treatment plants where it was mixed with water from other non-affected wells, processed, and then distributed. Detailed information may be found in tables published in reports by the Agency for Toxic Substances and Disease Registry (ATSDR) and the National Research Council of the National Academies (NRC) [please see Website Links of Interest]. The Navy and Marine Corps continue to work with leading scientific organizations in an effort to provide comprehensive science-based answers to the health questions that have been raised.

Drinking water at Camp Lejeune currently meets all government drinking water standards and is tested more often than required. For Camp Lejeune’s annual water quality reports, please see: <http://www.lejeune.marines.mil/Offices-Staff/Environmental-Mgmt/Annual-Reports/>.

This brochure presents a series of questions and answers to explain issues regarding Camp Lejeune’s historic drinking water.

Questions and Answers

HISTORY OF DISCOVERY

Q: When and how were the chemicals in drinking water discovered and addressed? Were there drinking water regulations for these chemicals at the time?

A: In the early 1980s, Camp Lejeune began to test drinking water for trihalomethanes (THMs) because of new regulations that had been announced by the EPA for those chemicals. THMs are chemicals that are created when water is treated with chlorine. While these initial tests for THMs were being conducted, other chemicals, unidentified at the time, were sometimes interfering with the results. Through special testing of the drinking water system in 1982, the chemicals causing the interference with THM testing were identified as TCE and PCE. The test results varied between drinking water samples collected at different times. Base officials were unable to immediately identify the source of the chemicals. Beginning in 1984, as part of the environmental cleanup program, some drinking water wells were tested near potential former disposal sites. Benzene, a volatile organic compound, was found in one of the wells serving the Hadnot Point water system. When base officials were notified of the result, the well was taken out of service on the same day it was found to be affected, and a more comprehensive well testing effort began. When this testing identified volatile organic compounds in specific drinking water wells, the affected wells were removed from service. There were no drinking water regulations established for these chemicals at that time.

OUTREACH AND REGISTRATION

Q: When did the Marine Corps notify people about the drinking water problem?

A: Our outreach efforts began in 1984 following the discovery of chemicals in the drinking water wells. The base newspaper ran an article in December 1984. In May 1985, the Marine Corps held a press event which resulted in multiple articles in local newspapers. In 2000-2001, we helped recruit participants for a health study being conducted by the ATSDR through an extensive notification effort through the media and military messages. Today, we continue to engage in community outreach and world-wide notification activities through press releases, public notices in newspapers and magazines, website announcements and direct mailings. We have established a drinking water Notification Database that now includes over 250,000 individuals. For the most current registrant count, visit www.marines.mil/clwater.

Q: How can I register?

A: Register at www.marines.mil/clwater or through the Call Center at (877) 261-9782.

Q: How do I update my information?

A: Please contact the Toll Free Call Center at (877) 261-9782 and they will update your contact information, or go to the front page of our website: www.marines.mil/clwater.

HEALTH AND ENVIRONMENT

Q: Is the water at Camp Lejeune safe to drink?

A: The drinking water at Camp Lejeune currently meets all government drinking water standards, and is tested more often than required. For Camp Lejeune’s annual water quality reports, please see: www.lejeune.marines.mil/OfficesStaff/EnvironmentalMgmt/AnnualReports.aspx.

Q: Who may have been exposed?

A: Best estimates from ATSDR’s water modeling efforts indicate that some of the base’s water was affected by chemicals as early as 1953 until as late as 1987.

Q: Could my health condition be related to chemicals in the drinking water?

A: We do not know if past exposure to these chemicals in Camp Lejeune’s drinking water caused adverse health effects in specific individuals. We continue to work with leading scientific organizations in an effort to provide comprehensive science-based answers to the health questions that have been raised. Information about completed, and ongoing, ATSDR studies can be found by visiting: <http://www.atsdr.cdc.gov/sites/lejeune>.

Q: What should I do about any medical condition I may have or suspect I have?

A: We encourage you to contact your family physician regarding any concerns you may have about your health or your family’s health. To receive updated information, please sign up on our Notification Database by either calling the Call Center or visiting www.marines.mil/clwater.

Q: How will I know when ATSDR studies are complete?

A: Upon conclusion of ATSDR studies, the Marine Corps will notify individuals registered in our Notification Database via mail and email, and broader notification will occur via media outlets and announcements on the Marine Corps website.

Q: Are there health benefits that may be available to me?

A: On August 6, 2012, President Barack Obama signed into law the “Honoring America’s Veterans and Caring for Camp Lejeune Families Act of 2012.” Veterans and family members who served on active duty or resided at Camp Lejeune for 30 days or more between January 1, 1957 and December 31, 1987 may be eligible for medical care for 15 health conditions. The VA has also proposed regulations to provide disability benefits for eight health conditions. The Department of Veterans Affairs offers more information about benefits and eligibility at <http://www.publichealth.va.gov/exposures/camp-lejeune>.

